

## ACTIVE GROUND CURRENT REDUCTION DEVICE

### BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention relates to the field of electronics. More  
5 specifically, this invention relates to a device that allows the transfer of power from  
a grounded external source to an electrical apparatus in those instances where  
there is a limit on the ground current due to shock hazard. In this disclosure, the  
term "ground current" refers to any current flowing through the ground connection  
of the external grounded source. This same current is also referred to as "common  
10 mode current." The term "common mode voltage" refers to any voltage which can  
act as a source of ground current.

#### Description of the Related Art

Many electronic components today contain features for protection  
against electrical shock. Generally speaking, these features provide monitoring to  
15 determine if there is electricity discharging where it should not be, or leaking.  
When electrical leakage is detected, the features are designed to turn components  
off in order to protect against shock. In an instance such as charging of a battery,  
turning off of the components may prevent such desired charging. Accordingly, a  
need is recognized for a device that detects electrical leakage and is able to  
20 capture the leakage without turning other components off.

Referring to Figure 1, an exemplary circuit for reducing ground  
current from an active load back through a main source is illustrated. Since Figure  
1 only illustrates an equivalent circuit for ground current, there may be additional  
sets of elements not shown therein. As shown, a grounded voltage source 12 is  
25 connected to a device 10, which in turn is connected to a load 18. The load 18 is  
considered to contain, in part, active circuitry such as switching devices that

generate high frequency voltages with respect to the grounded enclosure, which in turn source current to the grounded enclosure through capacitance existing between the active circuitry and the grounded enclosure. Figure 1 is solely intended to be the equivalent circuit for ground current and does not represent intended power flow between the source 12 and the load 18. For example, the exemplary circuit can be a charging system with the grounded voltage source 12 being an outlet, the device 10 being a filter for reducing load sourced ground current and the load 18 being a battery charger for charging a battery. The grounded voltage source 12 generates a common mode voltage that typically consists of low frequencies in value ranging from dc up to several hundred hertz ("Hz."). For example, if the source 12 is from a standard utility, the frequency of the common mode voltage would be 50 Hz in Europe and 60 Hz in the United States, if the source 12 is an airborne source the frequency could be 400 Hz. Similarly, a ground current is associated with the load with ground current consisting of higher frequency components typically ranging in value from several kHz to several MHz.

The load 18 must be powered from a grounded supply in such a way that the total ground current is kept below a given level to avoid a shock hazard. Moreover, circuits such as that shown in Figure 1 typically contain a ground fault detector (not shown) that shuts down the device 10 if ground current is excessive. For example, if no filter was present in Figure 1, the ground current from the source would be low and the ground current from the load would be high, causing the device 10 to shut down. Thus, as known in the art, a filter positioned between the voltage source 12 and the load 18 assists in keeping the ground current from the load 18 within the device 10. As illustrated, the filter consists of an inductor  $L_1$  14 and a capacitor  $C_1$  16. By increasing the capacitance of capacitor  $C_1$  16, the amount of ground current passing through the device 10 is reduced, or more specifically, the amount of ground current from the load 18 is reduced. However, by increasing the value of capacitor  $C_1$  16, the ground current from the common mode voltage source 12 into the device 10 increases, which can result in an

unwanted discharge, e.g., a shock. The shock hazard results from the return line (not shown) containing a voltage higher than ground.

Thus, there is an optimum capacitance value for capacitor  $C_1$ , resulting in a minimum value of ground current from the common mode voltage source 12. However, in some situations this minimum value of ground current from the common mode voltage source 12 is still above a maximum allowable level. Accordingly, there is needed a device which keeps the load ground current enclosed within the apparatus without limiting the total amount of filtering that may be achieved.

## 10 BRIEF SUMMARY OF THE INVENTION

In the disclosed embodiment, the present invention alleviates the drawbacks described above with respect to the transfer of power without exceeding a safe level of ground current. The present invention utilizes a controlled voltage source in series with a capacitor or a filter for canceling or substantially reducing ground current from an external power source and reducing the ground current from a load.

In one embodiment, a device is inserted between a grounded poly-phase external voltage source and a load providing low insertion loss for differential mode currents and high insertion loss for ground current. The device includes at least one voltage line, a filter, a summing block, and a ground referenced controlled voltage source. The at least one voltage line receives at least one voltage from the grounded poly-phase external voltage source with the at least one voltage having a common mode voltage. The filter is connected to each of the at least one voltage lines and is configured to reduce the ground current from the load. The summing block is configured to add the voltages from each of the at least one voltage lines to generate a total common mode voltage. The ground referenced controlled voltage source generates a cancellation voltage equal to the total common mode voltage in response to the generation of the total

common mode voltage. The total common mode voltage is injected into the filter and substantially reduces the common mode voltage on each voltage line thereby substantially reducing ground currents associated with each common mode voltage on each voltage line.

- 5                    In one embodiment, a method for providing low insertion loss for differential mode currents and high insertion loss for ground currents for a device between a grounded poly-phase external voltage source and a load. The method includes the steps of receiving at least one voltage from the external source via at least one voltage line, reducing the ground current from the load using a filter,
- 10                   summing the voltage from the at least one voltage line, generating a cancellation common mode voltage equal to the sum of the summed voltages, and injecting the cancellation common mode voltage into the filter. By injecting the cancellation common mode voltage into the filter, the common mode voltage on each voltage line is substantially reduced which substantially reduces the ground current on
- 15                   each voltage line.

                    The general beneficial effects described above apply generally to each of the exemplary descriptions and characterizations of the devices and mechanisms disclosed herein. The specific structures through which these benefits are delivered will be described in detail herein below.

## 20    BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

                    In the following, the invention will be described in greater detail by way of examples and with reference to the attached drawings, in which:

                    Figure 1 is an illustration of an exemplary circuit for reducing ground current from an active load back through a main source according to the prior art;

- 25                   Figure 2 is an illustration of a circuit for reducing the ground current from a source according to one embodiment of the present invention;

Figure 3 is an illustration of the circuitry of an active circuit for reducing ground current from a source according to one embodiment of the present invention;

Figure 4 is an illustration of an ideal active circuit for reducing ground  
5 current from a source according to one embodiment of the present invention; and

Figure 5 is an illustration of an actual active circuit for reducing ground current from a source according to one embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

10 As required, detailed embodiments of the present invention are disclosed herein. However, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale and some features may be exaggerated or minimized to show details of particular components. Therefore,  
15 specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention.

Furthermore, elements may be recited as being "coupled." This terminology's use contemplates elements being connected together in such a way  
20 that there may be other components interstitially located between the specified elements, and that the elements so specified may be connected in fixed or movable relation one to the other. Certain components may be described as being "adjacent" to one another. In these instances, it is expected that a relationship so characterized shall be interpreted to mean that the components are located  
25 proximate to one another, but not necessarily in contact with each other. Normally there will be an absence of other components positioned there between, but this is not a requirement. Still further, some structural relationships or orientations may be designated with the word "substantially". In those cases, it is meant that the

relationship or orientation is as described, with allowances for variations that do not effect the cooperation of the so described component or components.

Referring to Figure 2, a circuit for reducing ground current from a source according to one embodiment of the present invention is illustrated. As shown, the circuit 20 contains an active circuit 22 in series with a capacitor  $C_1$  16 of the filter. In a preferred embodiment, the active circuit 22 determines the amount of common mode voltage from a source 12 and generates a voltage to cancel or substantially reduce the amount of common mode voltage. Thus, the active circuit 22 cancels the ground current from the source 12 and allows the capacitor  $C_1$  16 in the filter to be increased, thus further reducing the ground current generated by the load 18. In the preferred embodiment, the active circuit 22 is powered by an isolated power supply (not shown) that does not contribute to ground current. The function of this controlled voltage source is to generate a voltage for canceling the common mode voltage of the main source, while at the same time acting as a short circuit at the frequencies of the load ground current components. This controlled voltage source will then generate a ground current that will exactly cancel or substantially reduce the ground current generated by the source common mode voltage 12 that flows into the filter element C 16. By doing so, filter element C 16 may be made arbitrarily large in order to reduce the ground current generated by the load without increasing the source ground current. As a result, the circuit causes the insertion impedance of the common mode voltage to remain small at the frequencies of the load ground current.

Referring to Figure 3, an active circuit for reducing ground current from a source according to one embodiment of the present invention is illustrated. As shown, a summing block 30 measures or adds the voltages from each voltage line of the grounded n-phase voltage source 12. In the preferred embodiment, the grounded voltage source 12 is any of the standard utility configurations for electrical power distribution such as residential single phase three-wire systems providing 120 VAC line to neutral and 240 VAC line-to-line and commercial three

phase three and four wire systems. In an alternate embodiments, the grounded source can have an arbitrary number of low frequency phases, each with arbitrary frequency, phase amplitude and waveshape. For example, only one voltage is used for an unbalanced single phase voltage source, two voltages are added for a  
5 balanced single phase voltage source and three or more voltages are added for a balanced poly-phase of N-phases. Specifically, the common mode voltages are measured at the input of the filter.

The summing block 30 adds the voltages together to form voltage VA. A controlled voltage source 32 generates voltage VB that equals voltage VA.  
10 In the preferred embodiment, the controlled voltage source 32 is a ground referenced controlled voltage source. Thus, the controlled voltage source injects a voltage into the circuit, thereby canceling or substantially reducing the source common voltage resulting in zero ground current. In other words, the filter, inductors 14a-14n and capacitors 16a-16n cancel or substantially reduce the  
15 common mode voltage on each voltage line.

Referring to Figure 4, an ideal active circuit for reducing ground current from a source according to one embodiment of the present invention is illustrated. As shown, the summing block comprises an operational amplifier AI (op amp) 48 configured as a summing differential amplifier. As illustrated, resistors R1  
20 34a-34n, 36 and R2 38a, 38b are used to properly set the gain of the differential amplifier AI 48. In the preferred embodiment, transformer T1 40 serves as the controlled voltage source of Figure 3. Further, the product of the differential amplifier gain and transformer turns ratio is set equal to one, thereby providing voltage VB with a correct amplitude. The secondary of transformer T1 40 is  
25 grounded to give VB the correct reference. In the preferred embodiment, the primary of transformer T1 40 and resistor R2 38a, 38b are powered from a power supply independent of the N-phase source.

Figure 5 is an actual active circuit for reducing ground current from a source according to one embodiment of the present invention as illustrated.

Specifically, capacitor C<sub>2</sub> 50 shunts the output inductance of transformer T1 40 to ensure low impedance at high frequencies. The resistors R1 34a-34n, 36, R2 38a, 38b, and R3 46 and capacitors C1 44a-44n and C3 52 associated with the differential amplifier A1 48 compensate for the phase shift through the transformer  
5 T1 40 caused by winding resistances and leakage inductances.

Although the present invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken as a limitation. The spirit and scope of the present invention are to be limited only by the terms of any claims presented  
10 hereafter.

Industrial Applicability. The present invention finds applicability in the electronics industries, and more specifically in devices or applications wherein the load generates high frequency common mode voltage. Of particular importance is the invention's incorporation into utility connected non isolated power conversion  
15 devices.